Spacecraft Operations Development

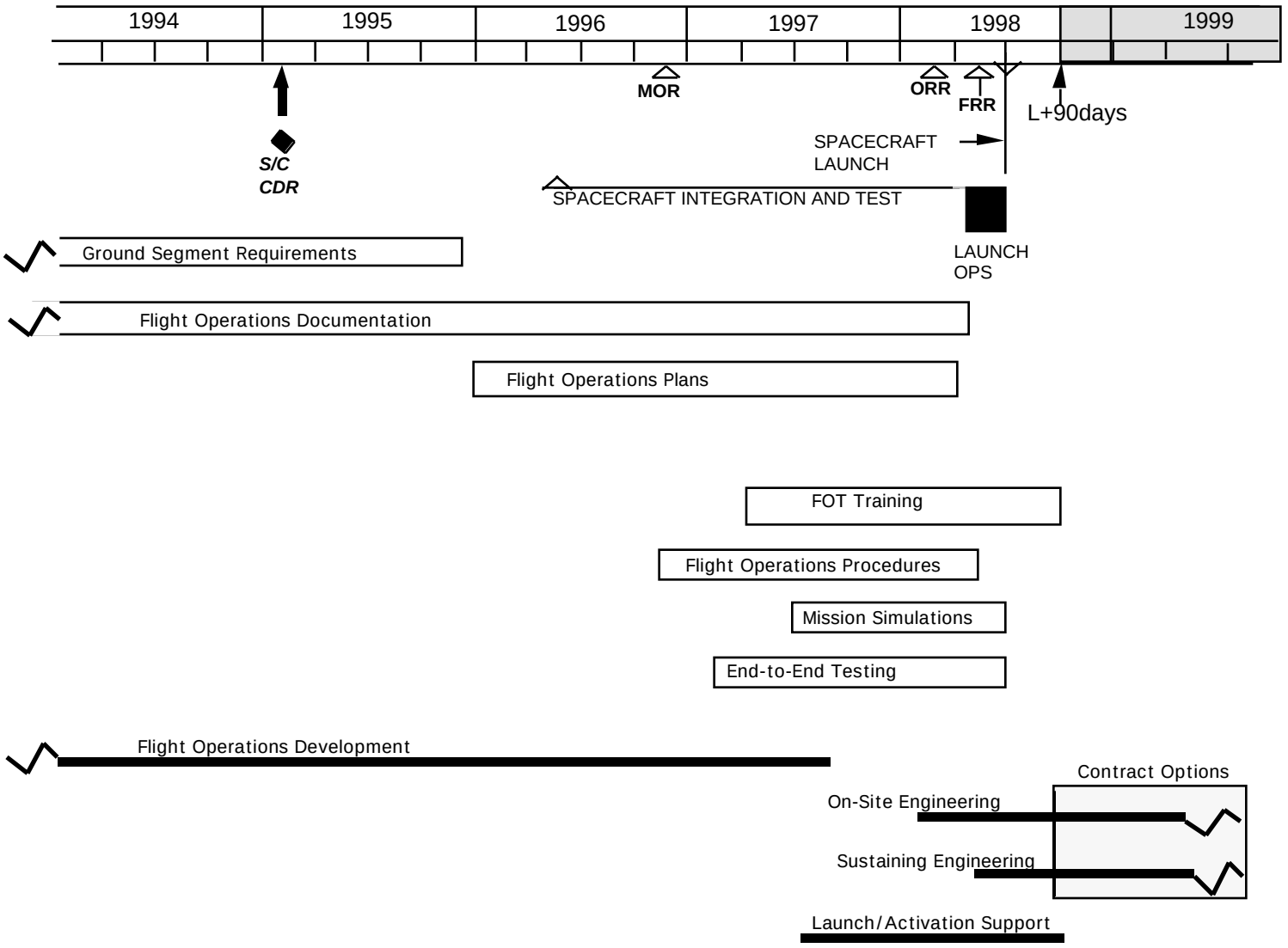
TOM SVOBODA
Spacecraft Operations Engineering
Lockheed Martin Missiles and Space
Valley Forge, PA
Email: tsvoboda@eos.vf.mmc.com

Spacecraft Operations Engineering

Support mission operations through Launch + 14 months by providing:

- **Flight operations systems engineering**
- **Spacecraft to ground system interface engineering**
- **Spacecraft operations documentation**
- **Engineering support to FOT for:**
  - **Procedure and display development**
  - **Training and simulations**
  - **Performance analysis and verification**
- **On-site support at GSFC beginning in 1998**
- **Off-site support by LMMS through Launch + 14 months**

Spacecraft Operations Development Schedule

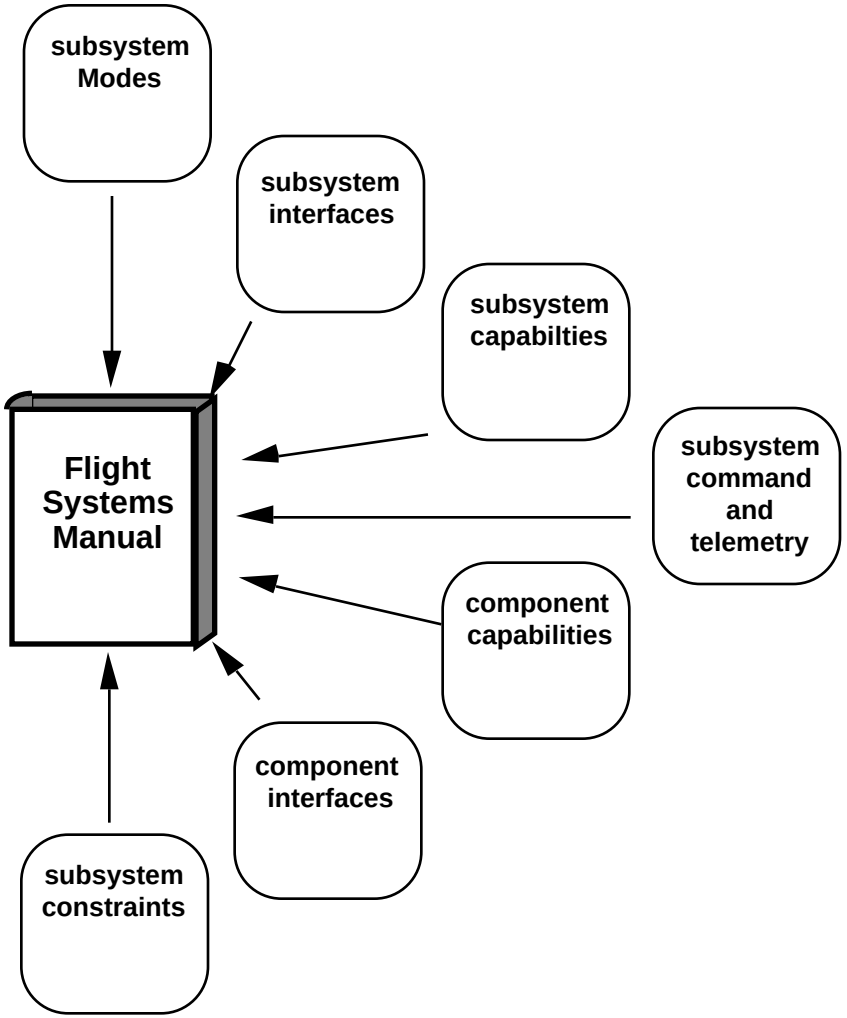


Spacecraft Operations Documentation

EOS AM-1 Spacecraft Operations Documentation:

- Operations Concept
- Flight Systems Manual
- Flight System Plan
- Flight System Operations Manual
- On-Orbit Operations Manual
- Flight Software Users Guide
- Instrument Operations ICDs
- Command and Telemetry definitions
- Spacecraft Trend Parameters/ Limited Life Items List
- FOT Training Materials

Flight Systems Manual

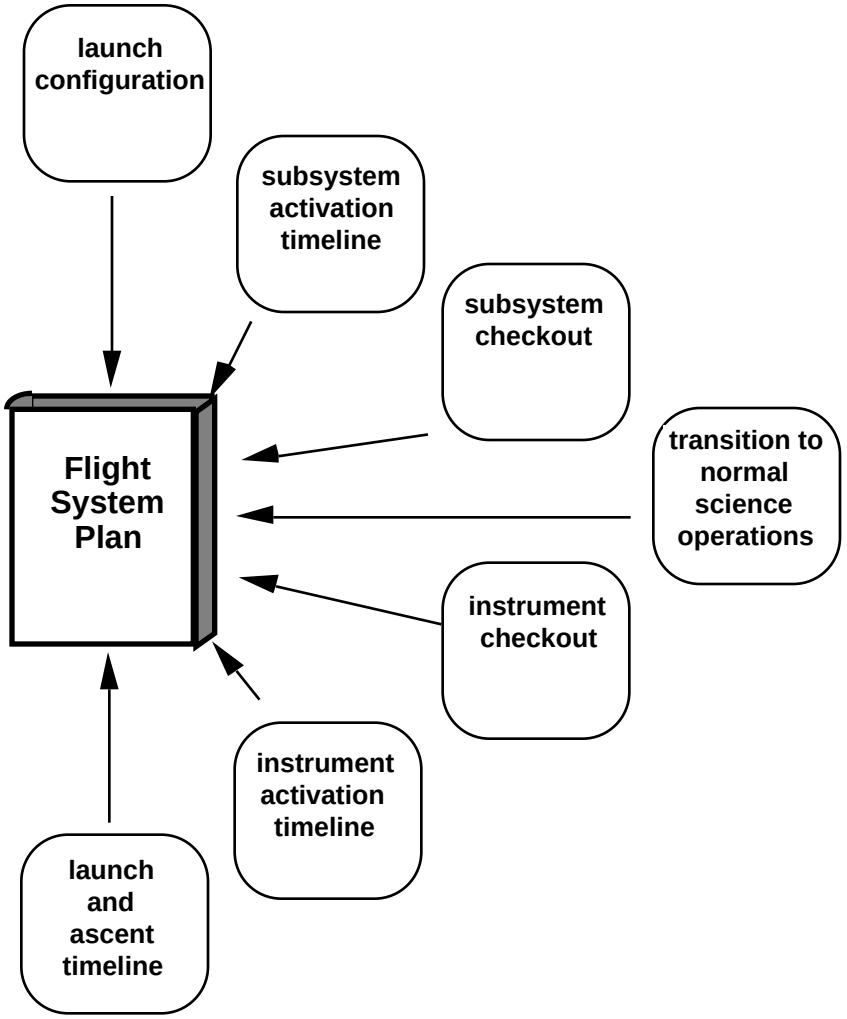


Delivered August 1996, update November 1997

Describes the design and capabilities of the AM-1 subsystems

- **Configuration and modes**
- **Component design(s)**
- **Capabilities and interfaces**
- **Command and telemetry**
- **Operations constraints**

Flight System Plan

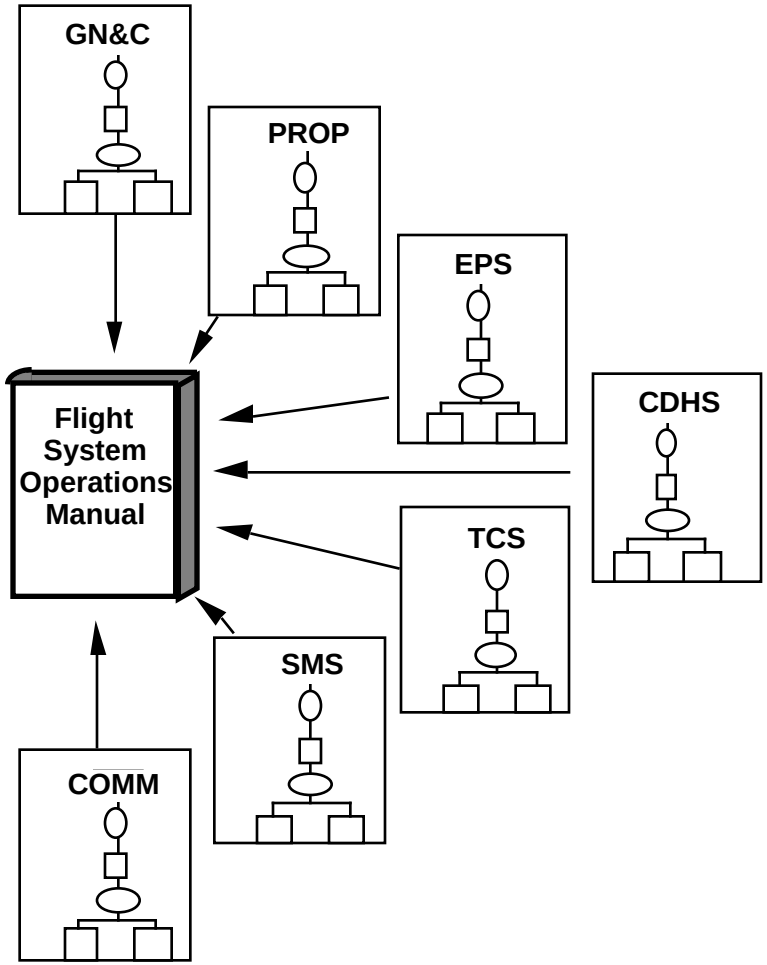


Draft November 1996, Final March 1998

Documents the AM-1 mission timeline from launch through transition to nominal science operations

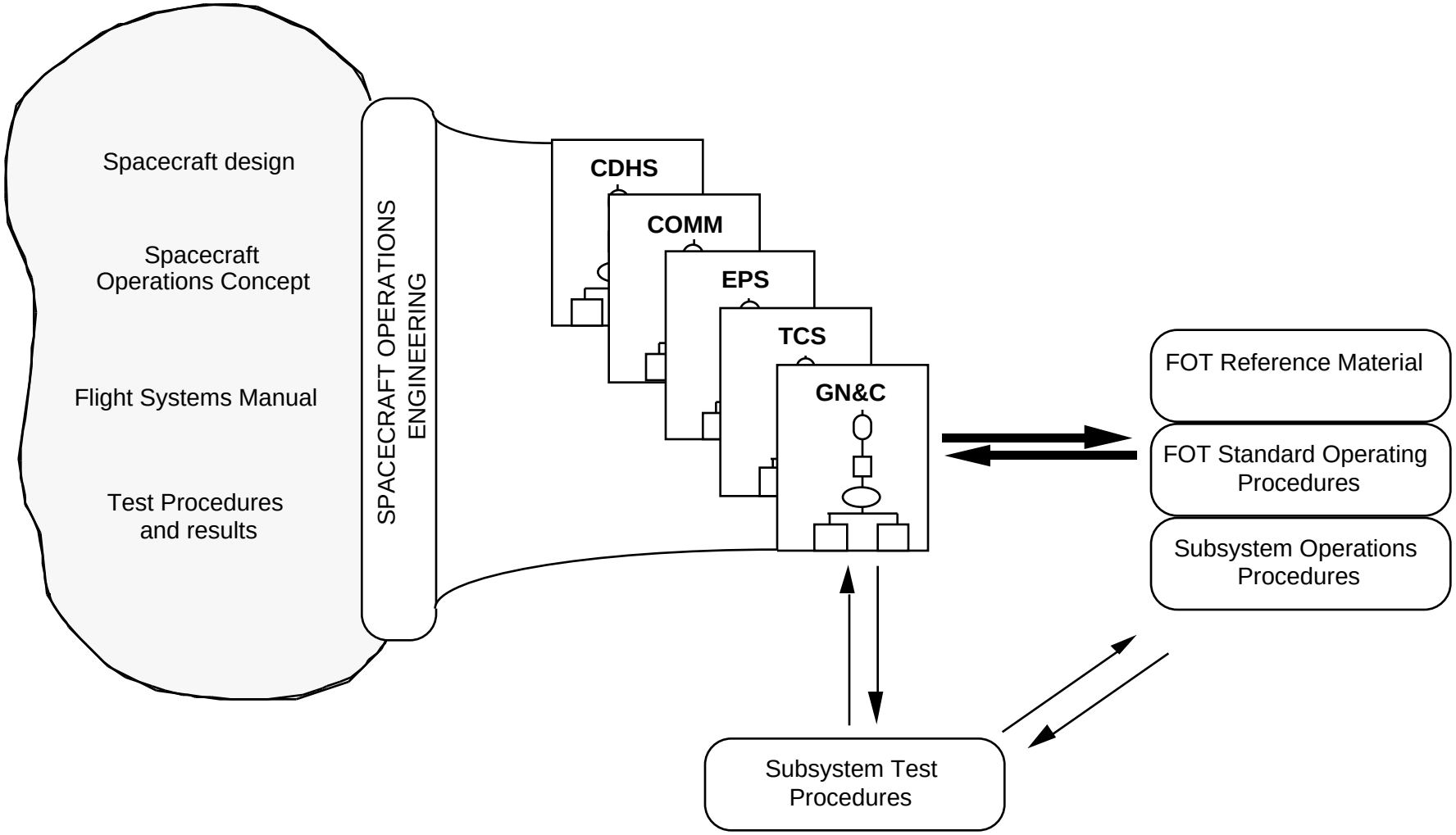
- **Mission phases**
- **Critical L&EO events: initial communications, earth acquisition, array and antenna deployments, mission orbit acquisition**
- **Spacecraft activation timeline**
- **Subsystem and instrument checkout plans**
- **Transition to normal science**

Flight System Operations Manual



- Draft March 1997, Final October 1997
- Describes the nominal, special, and contingency operations of the AM-1 subsystems
- Provides a description of each unique subsystem operation
  - Initial/prerequisite conditions
  - Command sequence and timing
  - Verification telemetry
  - Final conditions
- Provided to the FOT for use in developing flight Procs
- Provides a list of contingency operations

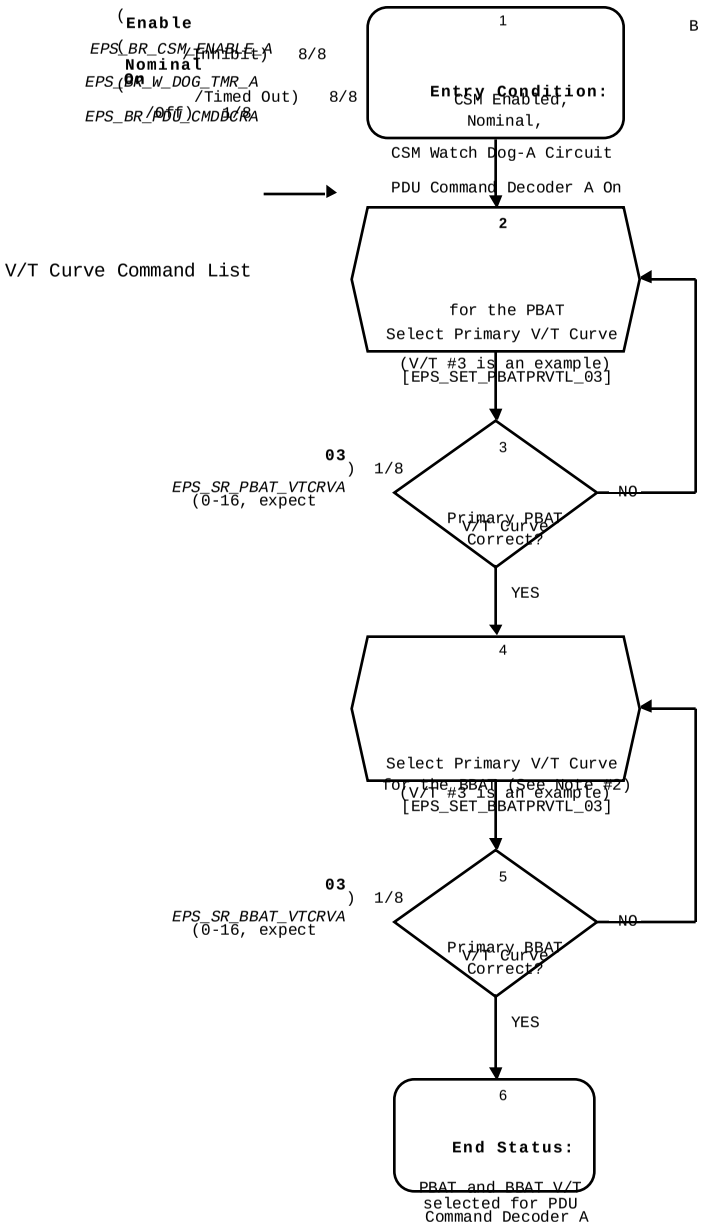
Flight System Operations Manual Development Process



Operations Flow - Example
EPS - change V/T level

Example:

Select V/T #3



(Enable /Inhibit) 8/8 *EPS_BR_CSM_ENABLE_A*

Nominal /Timed Out) 8/8 *EPS_BR_W_DOG_TMR_A*

On /Off) 1/8 *EPS_BR_PDU_CMDDCRA*

V/T Curve Command List

03) 1/8 *EPS_SR_PBAT_VTCRVA* (0-16, expect

03) 1/8 *EPS_SR_BBAT_VTCRVA* (0-16, expect

Note:

Normally both the A-side and the B-Side of the Command Decoder are ON.

Note:

Must be in Normal Mode which is defined as the capability of selecting any combination of Mode autonomously. Battery ready to receive commands while being charged under V/T control.

Note:

Trend the Battery Temperature and Voltage to verify that the actual V/T curve for the PBAT is correct.

Note:

The same Voltage/Temperature Curve shall be selected for both the PBAT and BBAT under normal operation.

Note:

Trend the Battery Temperature and Voltage to verify that the actual V/T curve for the BBAT is correct.

HKS	Housekeeping/Safety Monitor
HKH	Housekeeping
BBAT	Hex Bay Battery
PBAT	Power Module Battery
PDU	Power Distribution Unit
V/T	Voltage/Temperature Curve

NOTE:

Telemetry mnemonics are *italicized* i.e. *EPS_BR_ADE_A_ON* (On /Off) 1/8 where (On /Off) is the status with the expected value and the 1/8 represents 1 sample for H&S and 8 samples for the HK every master cycle.

Commands - Enclosed in brackets [ ]

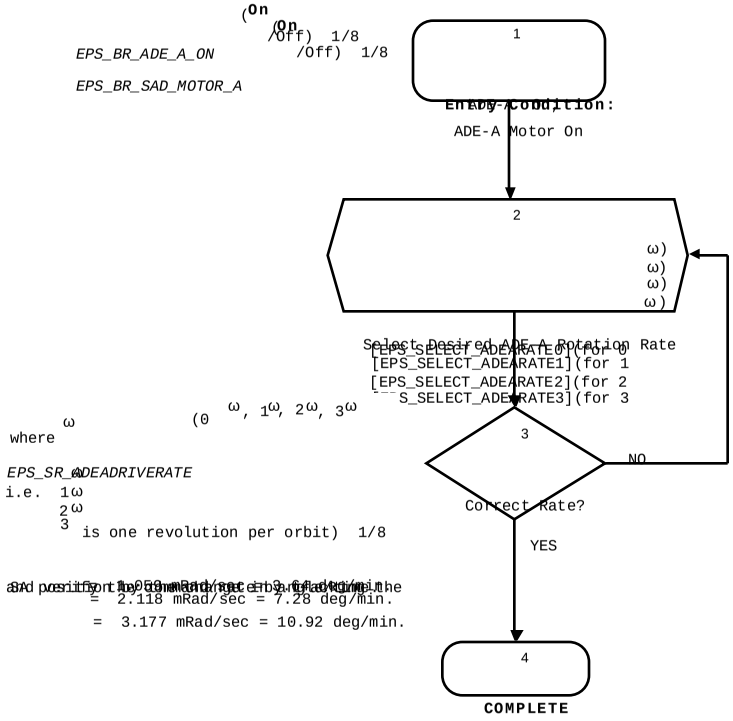
Telemetry - Followed by a number which represents the number of samples per master cycle for the Health and Safety/House keeping.

are followed by the possible values (in parenthesis) and by the # of

DATE OF LAST REVISION 11/04/96

REVISED BY: Eric Moyer

Operations Flow - Example
SAA Rate Change



Note:

ω

The SAD Motor doesn't need to be on in order to select the rotation rate. However, it is extremely important to have 0 selected before turning on the motor to prevent damage.

NOTE:

to change. Allow approximately 60 seconds for the SA rate

ω
H&S Health and Safety
ACE Attitude Control Electronics
SA Solar Array
SAD Solar Array Drive
Orbital Revolution

NOTE:

(On On

Telemetry mnemonics
i.e. *EPS_BR_ADE_A_ON*

/Off) 1/8 where (

Telemetry ***Italicized***

every master cycle. /Off) is the status with the expected

.

are followed by the possible values (in parenthesis) and by the # of samples per master cycle for the Health and Safety/House Keeping.

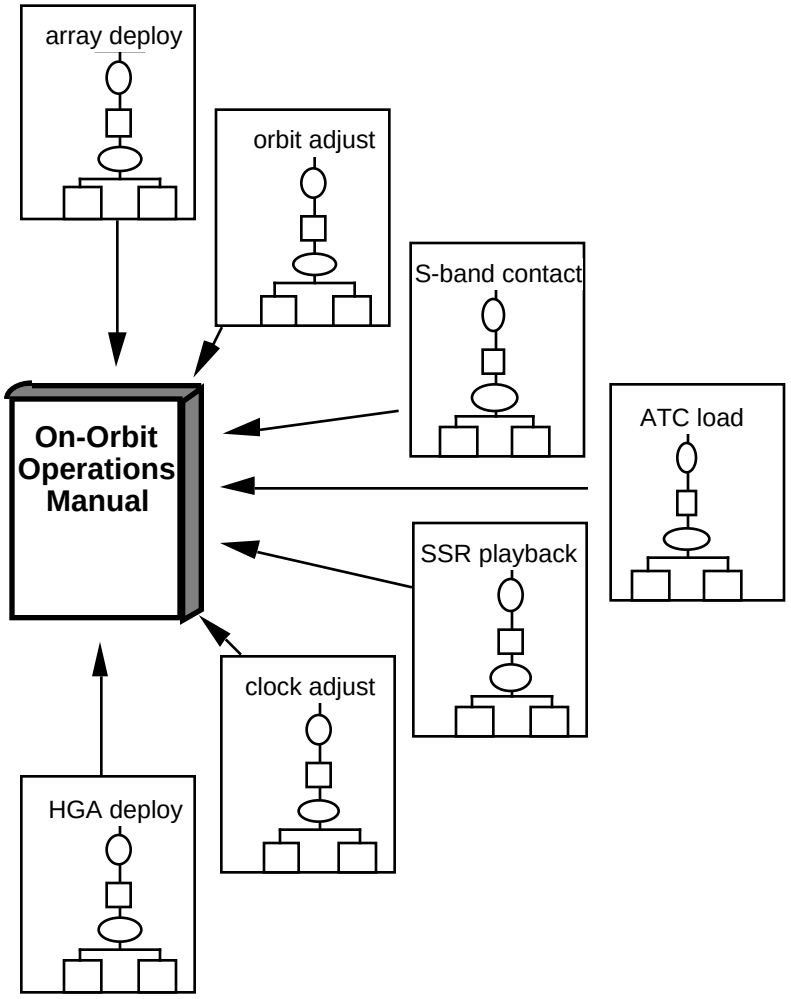
DATE OF LAST REVISION: 11/04/96

value in bold typeface and 1/8 represents 1 sample for H&S and 8 samples for the HK for

Commands = [within brackets]

REVISED BY: Eric Moyer

On-Orbit Operations Manual



Draft November 1997, Final April 1998

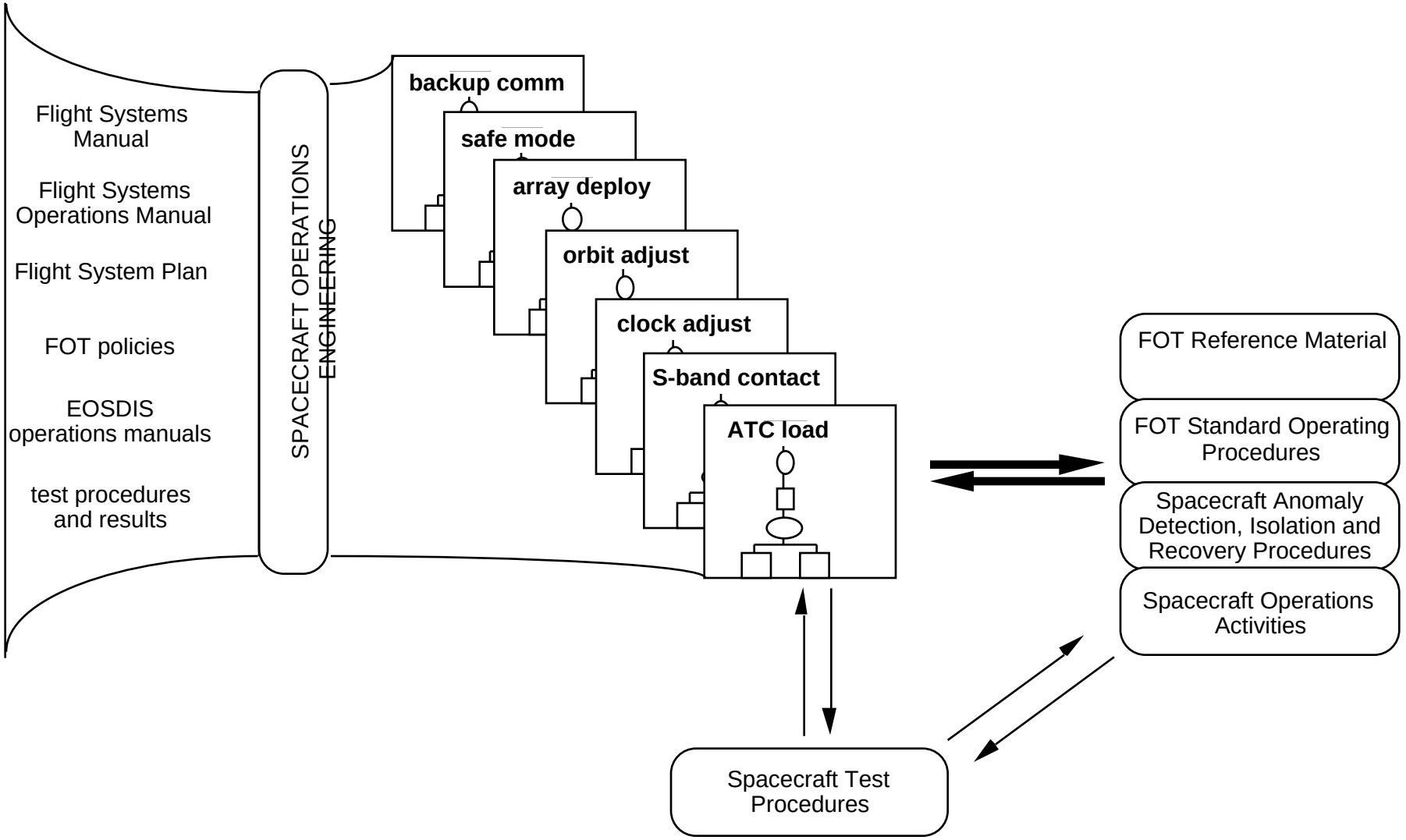
Provided to FOT for development of spacecraft activities and SOPs

Describes spacecraft nominal, special, and contingency operations

- **Initial / prerequisite conditions**
- **Planning and scheduling requirements**
- **Subsystem operations sequencing and timing**
- **Verification requirements (telemetry monitoring and/or analysis)**
- **Final conditions**

Provides decision trees for fault and anomaly detection, isolation and recovery

On-Orbit Operations Manual Development Process



Instrument Operations ICDs

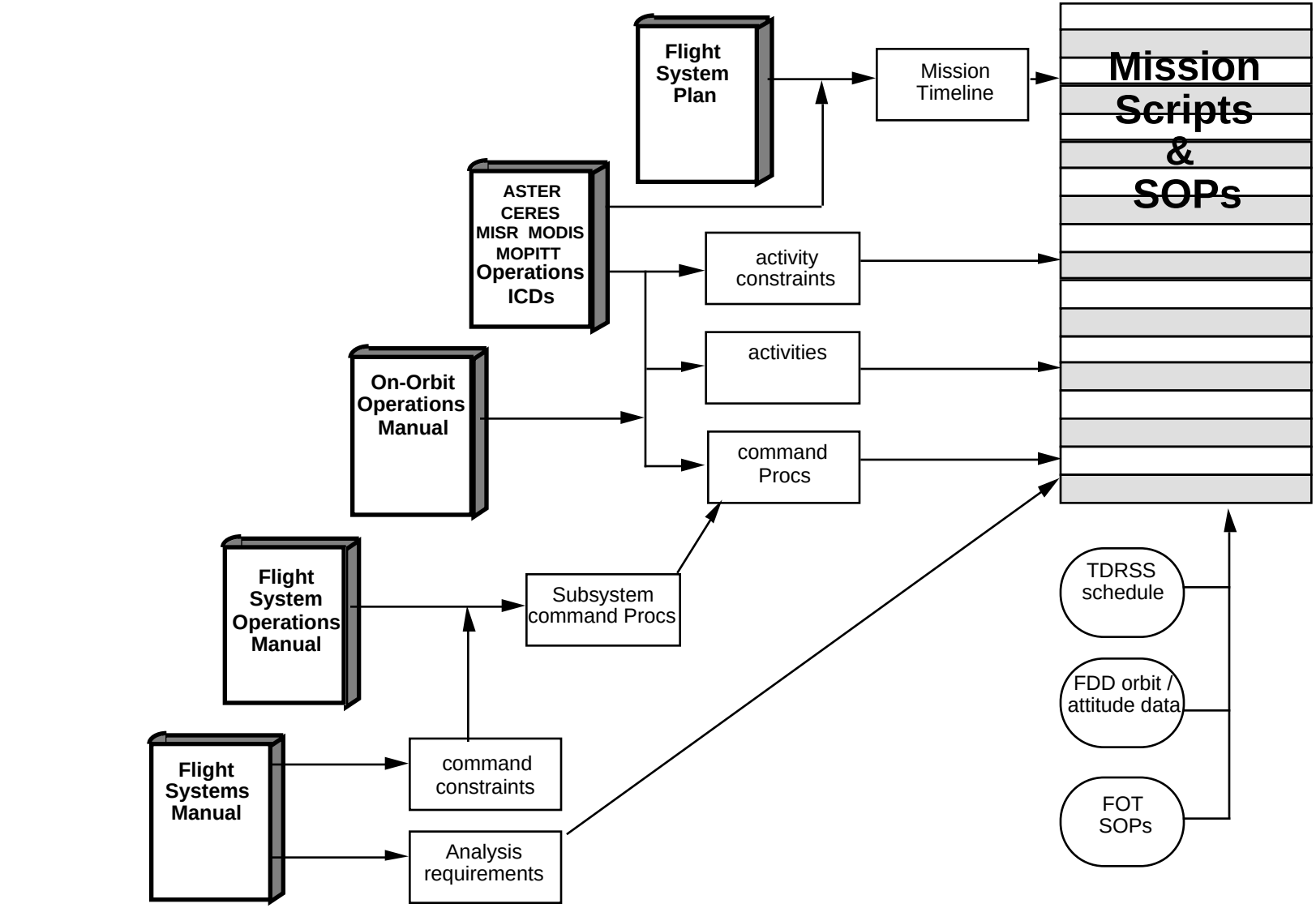
- Combine the Command and Telemetry ICD with the Instrument Flight Operations Understanding
- Documents the interface between the Instrument Operations Teams (IOT) and the FOT
  - Roles and responsibilities
  - Standard operating procedures
  - Operational agreements
- Describes instrument nominal, special, and contingency operations
  - Operational characteristics and constraints
  - Command Proc, Activity, RTCS and TMON descriptions
  - Command and Telemetry definitions*
- Signatories of the OICD include:
  - EOS AM and ESDIS Projects
  - Instrument, Spacecraft and ECS contractors
  - Instrument PI/TL

*ASTER Command and Telemetry definition contained within a separate C&T ICD

OICD Status

Instrument	Current Status	Signature
ASTER	Initial version in final update	December 1996
CERES	revision B in-process	February 1997
MISR	revision C in-process	December 1996
MODIS	revision B in-process	February 1997
MOPITT	revision A in-process	April 1997

Spacecraft Operations Documentation Development



Spacecraft Operations Tools

Spacecraft Simulator (SSIM) - July 1997

- Dynamic simulation of spacecraft bus for use in training simulations and procedure validation

Spacecraft Analysis System (SAS) - January 1998

- Suite of subsystem performance analysis tools for use in on-orbit performance verification and long term trending

Software Development Facility (SDF)- available now

- Software and hardware tools for design, code, test, and maintain spacecraft flight software

Flight Software Tools - July 1997

- Suite of tools provided to the SDF and FOT for operation of the flight software

Spacecraft Simulator

- From FSTB
  - CTIU and SCC (engineering models)
  - Hardware Models
    - » Deployment of SAA and HGA
    - » GN&C components (not ACE)
    - » Propulsion
    - » S-band transponder
  - Dynamic Models of the external environment, navigation and TDRS
  - Flight Software Model of Earth Acquisition control, magnetic unloading and HGA control
- Developed for SSIM
  - Complete telemetry responses to commands
  - Real time commanding support
  - Basic Power and Thermal Models
  - Basic ACE (Basic SHDP)
  - Standby CTIU
  - SSR & Science Formatting Equipment (SFE)

Spacecraft Analysis System

- Developed by Subsystem and Test engineers during spacecraft integration and test
- Suite of subsystem performance analysis tools used for:
  - On-orbit calibrations
    - » HGA pointing
    - » Propellant measuring
  - Subsystem/component performance verification
  - Long term performance trending

Software Development Facility

- Development environment for the AM-1 Flight Software
  - Software development tools
  - FSTB
- Used by
  - Software engineering for FSW development, code and test
  - Sustaining engineering for FSW maintenance
- Home of the master FSW image through Launch + 90 days
- Connected with the SCS
- Connected with the code 512 SDVF

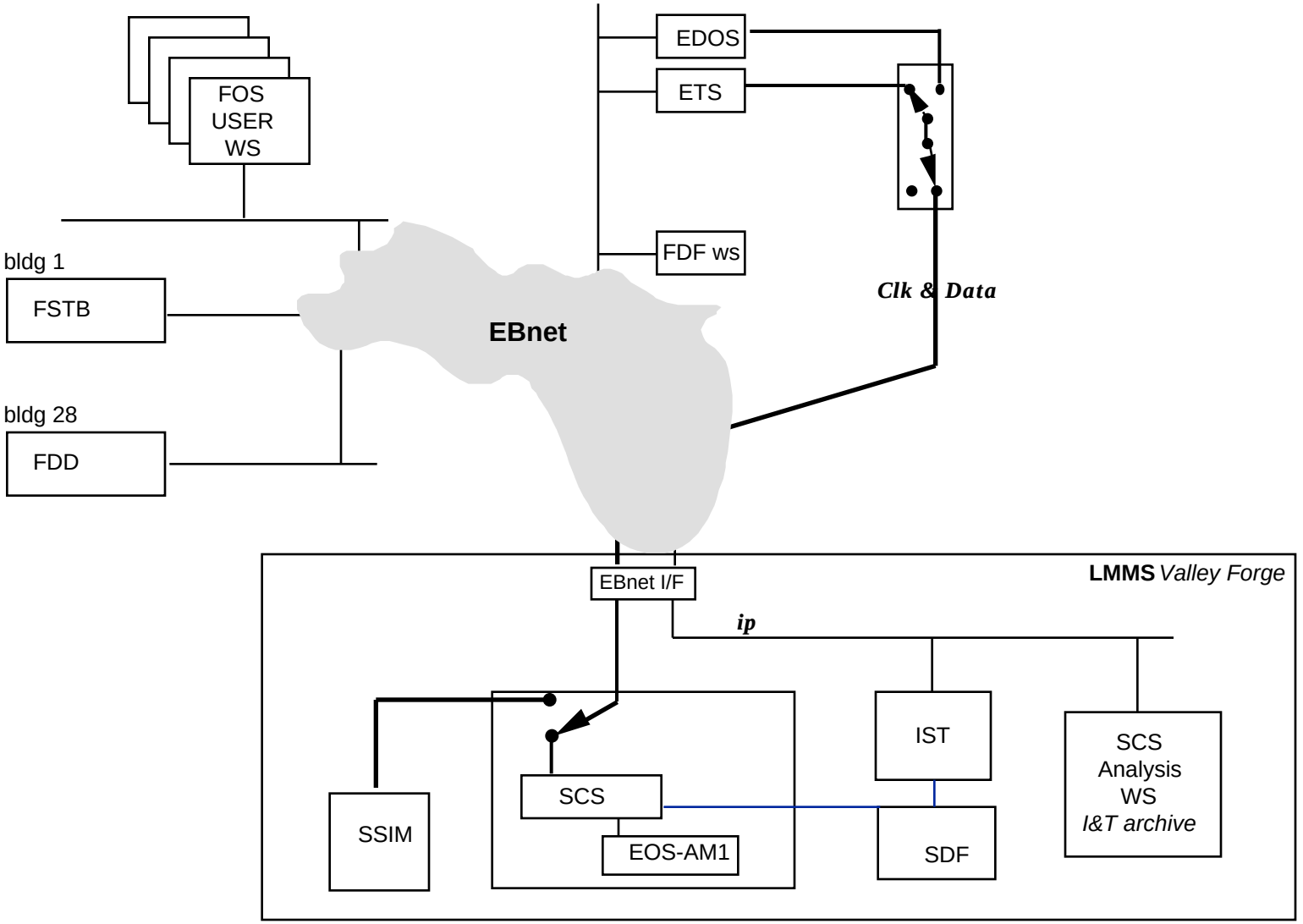
Flight Software Maintenance Support

- LMMS will retain FSW Maintenance responsibility through Launch +90 days
- SDF in VF will be maintained through Launch +90 days
- Prior to Spacecraft shipment
  - Software changes will be developed on the SDF in VF and transferred to the spacecraft via SCS
  - Deliveries of source code and executables will be made to Code 512 for the GSFC-FSTB to support IV&V and start up of software maintenance
- Prior to launch
  - Software changes will be developed on the SDF in VF and FTP'd to the SCS at Vandenberg Air Force Base (VAFB)
  - Changes will be delivered to the GSFC-FSTB

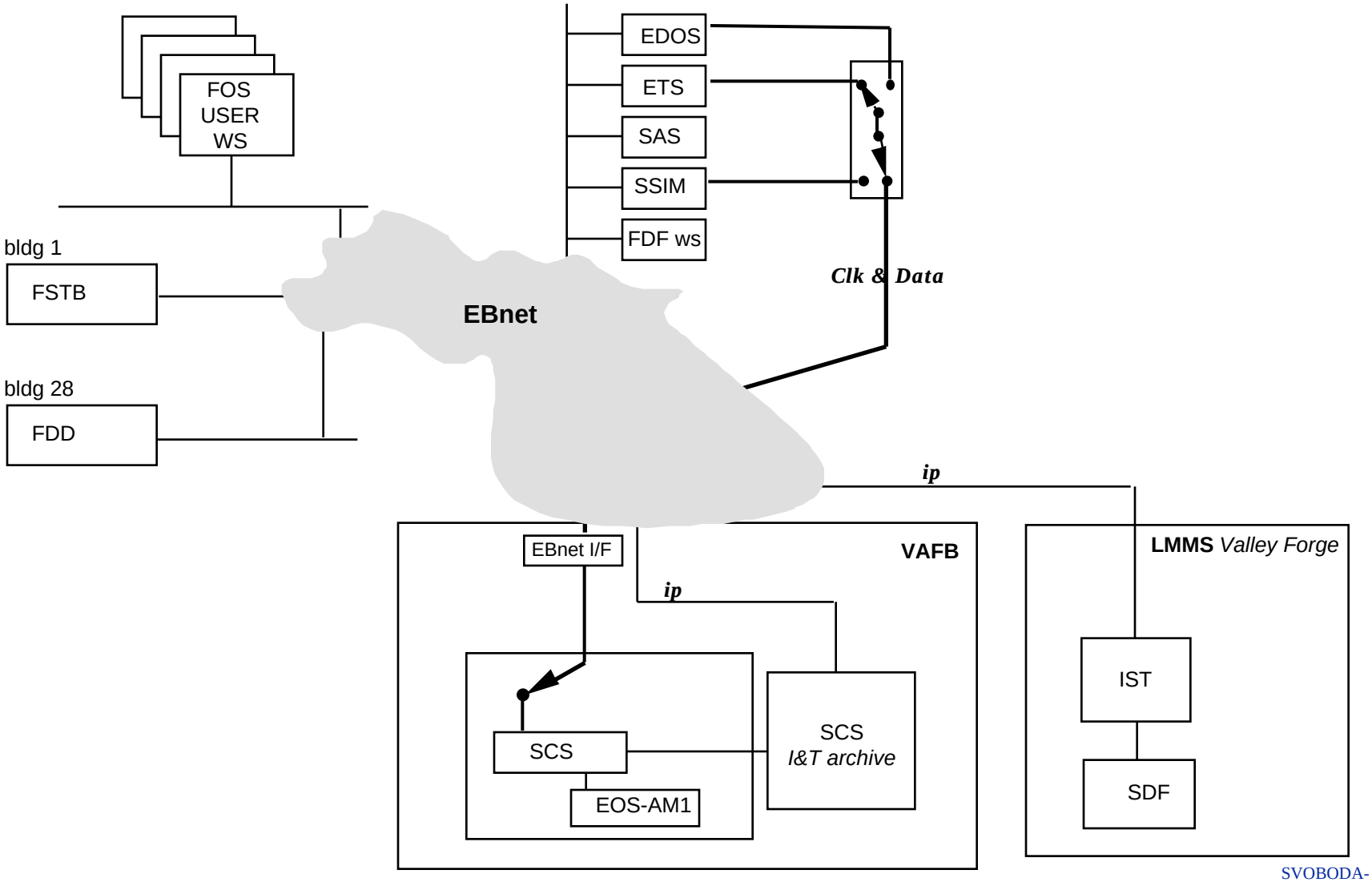
Flight Software Maintenance Support (Cont'd)

- Post launch until 90 days
  - Software changes will be developed on the SDF in VF and transferred to the EOC as a memory load, via the VF IS
  - In parallel, memory loads and source code changes will be transferred to the GSFC-FSTB
- Launch +90 days
  - Responsibility transfers to Code 512
  - Software changes will be developed on the GSFC-FSTB and transferred to the EOC as a memory load, via IST

FSW Maintenance
EOS AM-1 at LMMS VF



FSW Maintenance
EOS AM-1 at VAFB



FSW Tools

- TMON Builder
- Stored Command Load Formatter - ATC and RTCS
- Program Load Formatter - SCC SUROM and SCC FSW
- EEPROM Load Formatter - CTIU firmware and BUT
- Generic Table Builder - for flight software
- Command and Telemetry Bus table builder
  - BUT for CTIU
  - Telemetry Decom for SCC
- Generic cyclic redundancy check (CRC) calculator
- Activity Log Decoder

FOT Training

Spacecraft Operations and Subsystem Engineering will train the FOT for operation of the EOS AM-1 spacecraft, simulator and analysis system, by providing:

- **Training materials**
  - **Presentation charts**
  - **Operations documentation**
  - **Design reference documents**
- **Lectures**
- **Tutoring in the EOC**
- **Participation in training simulations**
- **Opportunities for FOT participation in Spacecraft tests**